# Fisheries Models:
# Methods, Data Requirements, Environmental Linkages


Richard Methot

NOAA Fisheries

Science & Technology

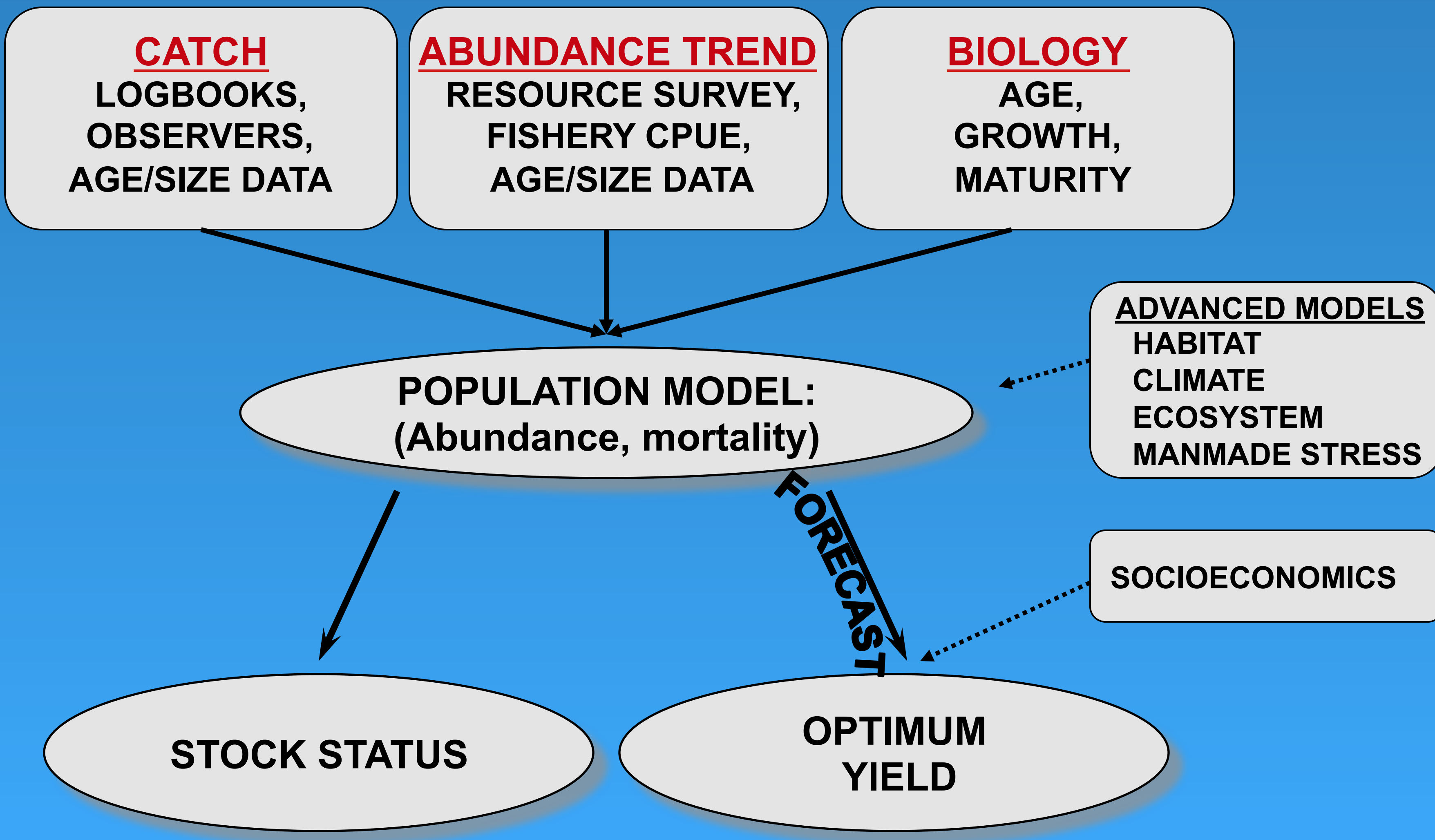
# PRESENTATION OUTLINE

- Assessment Goals
- What is a “Stock Assessment”?
- Data Inputs
- Assessment Methods
- Role of Environmental Data

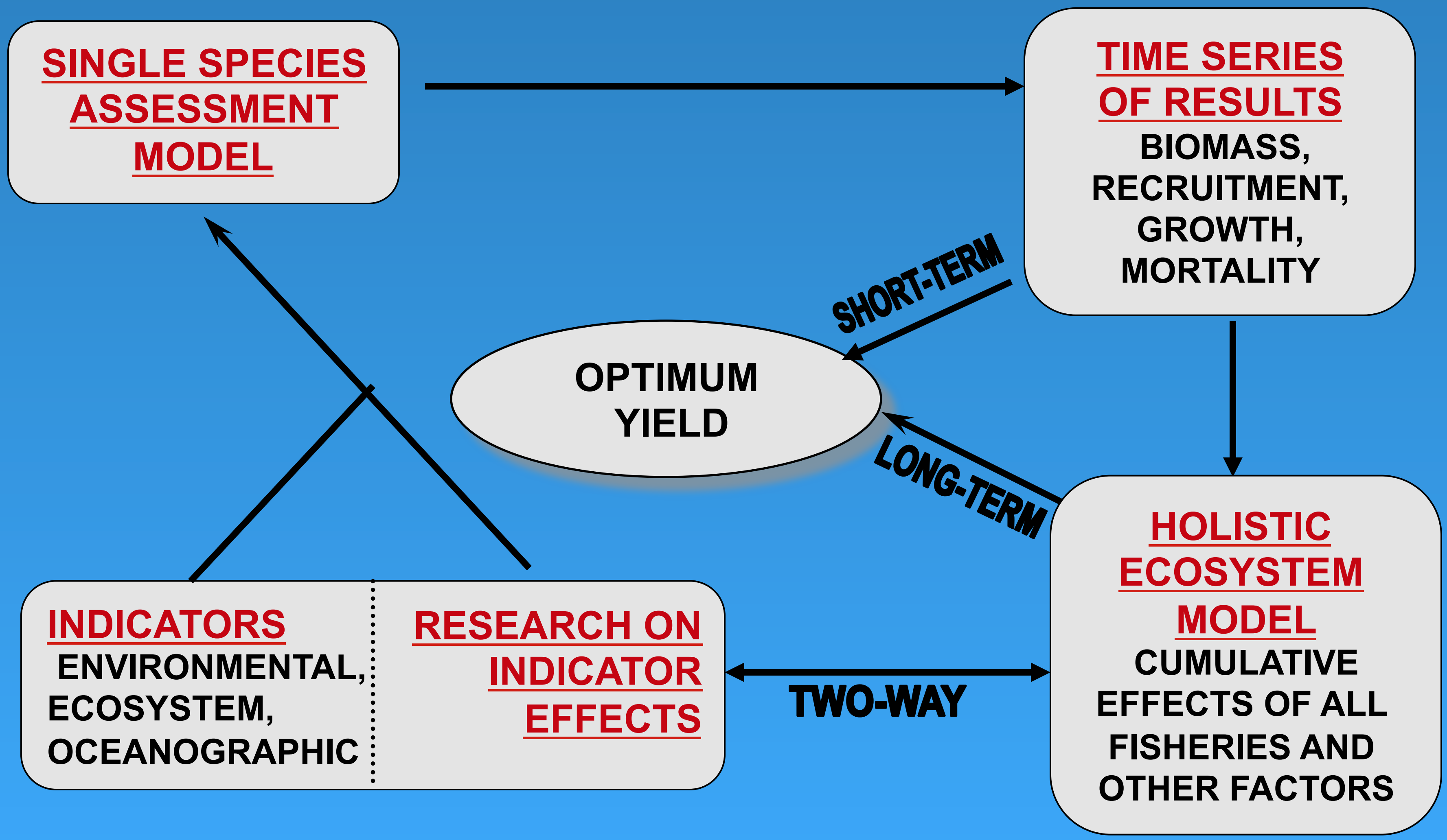
# Stock Assessment

- Collecting, analyzing, and reporting demographic information for the purpose of determining the effects of fishing on fish populations.
- Key Concepts / Jargon
  - Stock; Population; Unit
  - Abundance; Biomass; Spawning Biomass
  - Recruitment; Yearclass; Cohort
  - Fishery
  - Fishing mortality (F); Exploitation Rate

# STOCK ASSESSMENT PROCESS



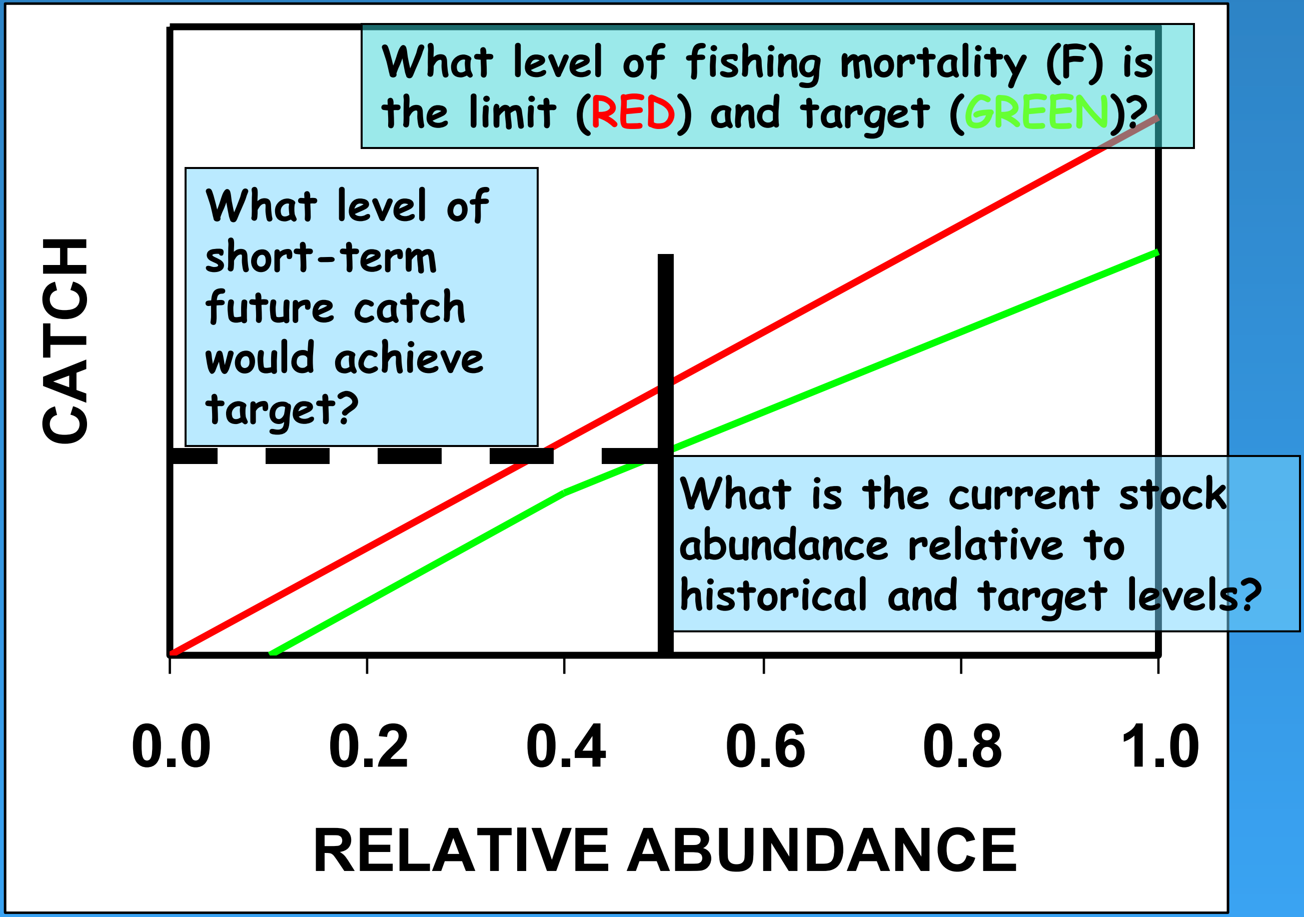
# STOCK ASSESSMENT & ECOSYSTEM



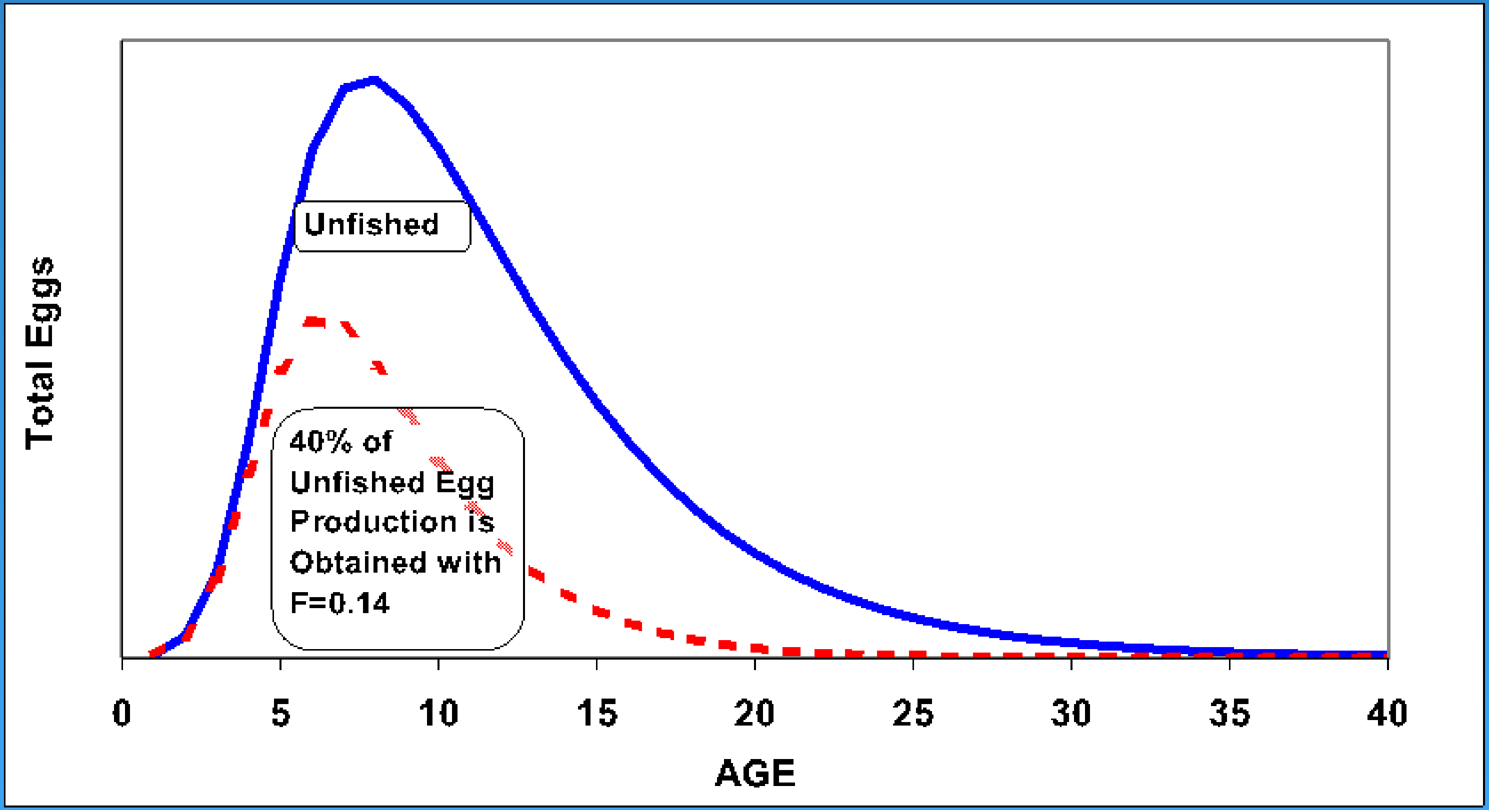
# Assessment Results
# Used in Fishery Management

- Monitoring / Reactive
  - Exploitation rate is higher than a maximum limit:
    - overfishing is occurring and must be eliminated;
  - biomass is below a minimum level:
    - the stock is overfished (depleted). A rebuilding plan must be prepared to rebuild the stock in as short a time as possible;
- Proactive
  - Assessment forecasts provide the technical basis (operational model) for setting and adjusting fishery quotas and other management measures to:
    - implement harvest policies
    - Rebuild depleted stocks

# HARVEST CONTROL RULE = OPERATIONAL MODEL

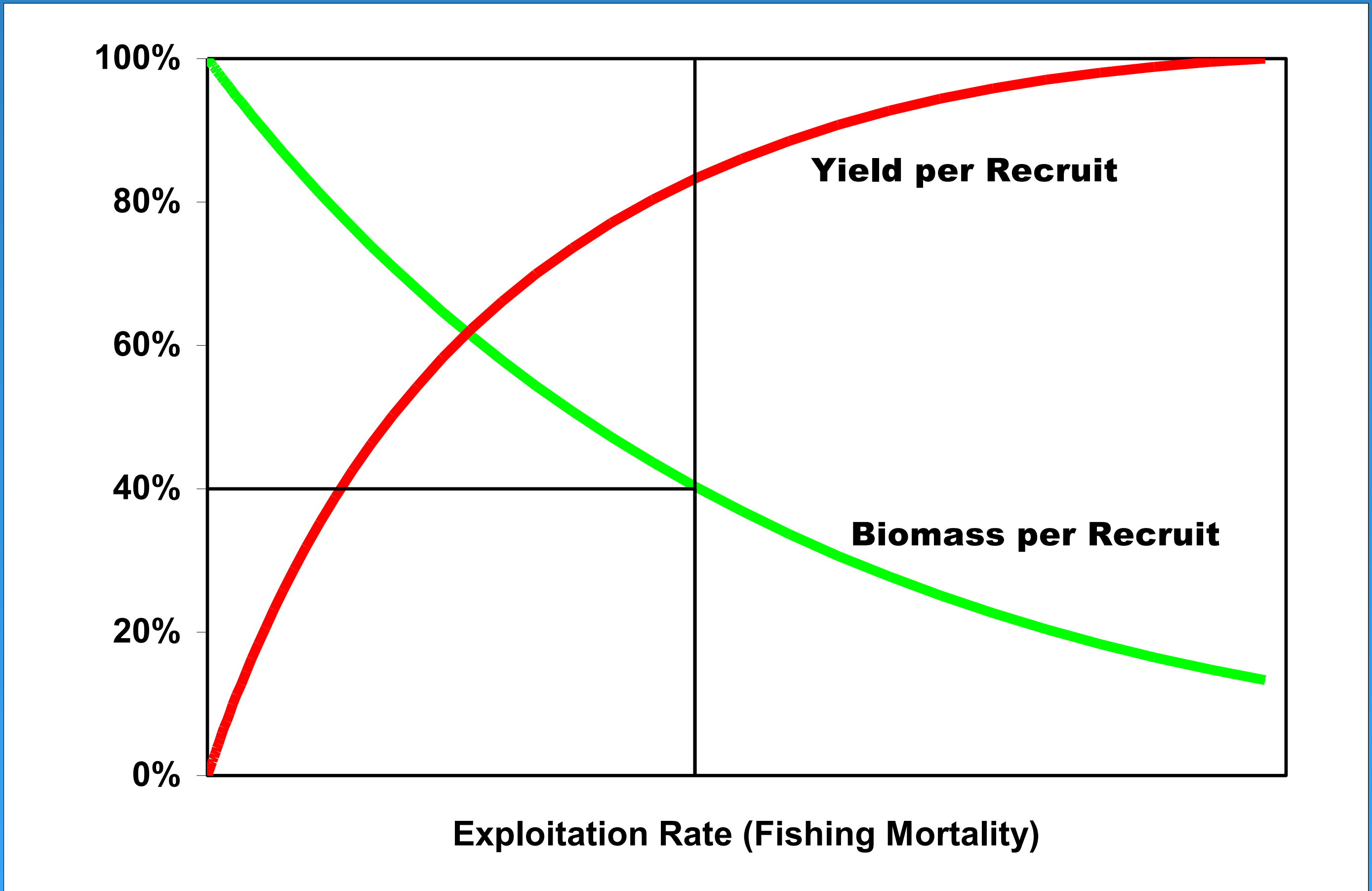


# FISHING REDUCES LIFETIME EGG PRODUCTION

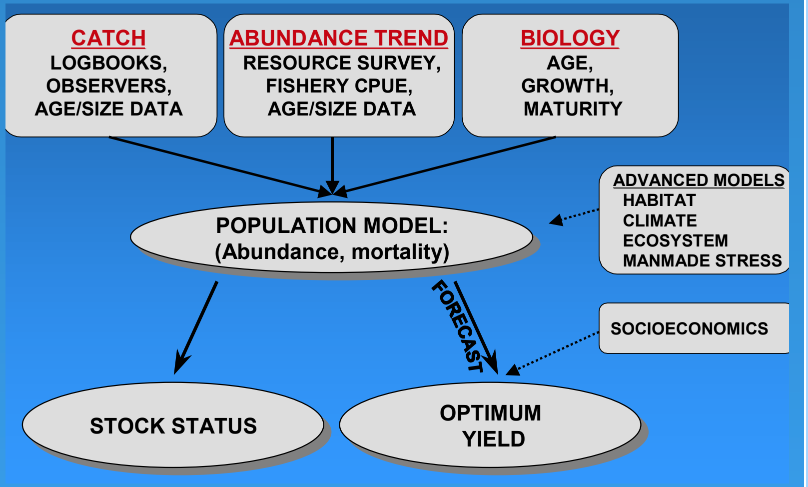


# DIRECT FISHING EFFECTS

## Yield per Recruit and Eggs (Spawning Biomass) per Recruit



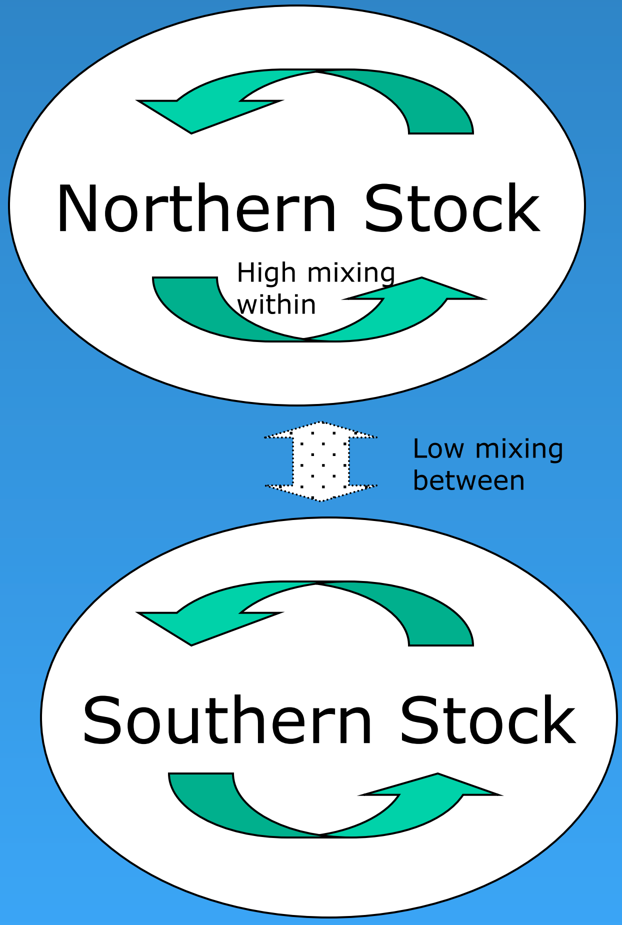
# Assessment Inputs




- STOCK STRUCTURE: Spatial limits of demographic unit
- TOTAL CATCH: total removals due to human activities (due to fishery landings, discarded bycatch, and cryptic mortality due to encounters with fishing gear);
- SURVEYS: the relative or absolute magnitude of a fish population (by age);
- LIFE HISTORY: growth, maturation, fecundity, natural mortality, and other characteristics of individual fish.

# What is a "Stock"?

- A group of individuals of the same species that:
  - inhabit the same geographic region;
  - interbreed when mature;
  - have sufficiently high levels of diffusion/mixing



# Pillar I - Catch Data
# Fisheries Information System

- Commercial fishing effort, catch, and value
  - Dealer reports
  - Vessel trip reports
- Recreational fishing effort and catch
  - Telephone surveys
  - Shoreside sampling surveys
- Size and age structure of catch
  - Commercial catch sampling surveys
  - Recreational catch sampling surveys
- Electronic dissemination of data
- Serves stock assessment, economic analysis, and fishery monitoring needs

# Fishery Observers

Since 1972 NOAA Fisheries has deployed fishery observers to collect catch and bycatch data from US and foreign commercial fishing and processing vessels.

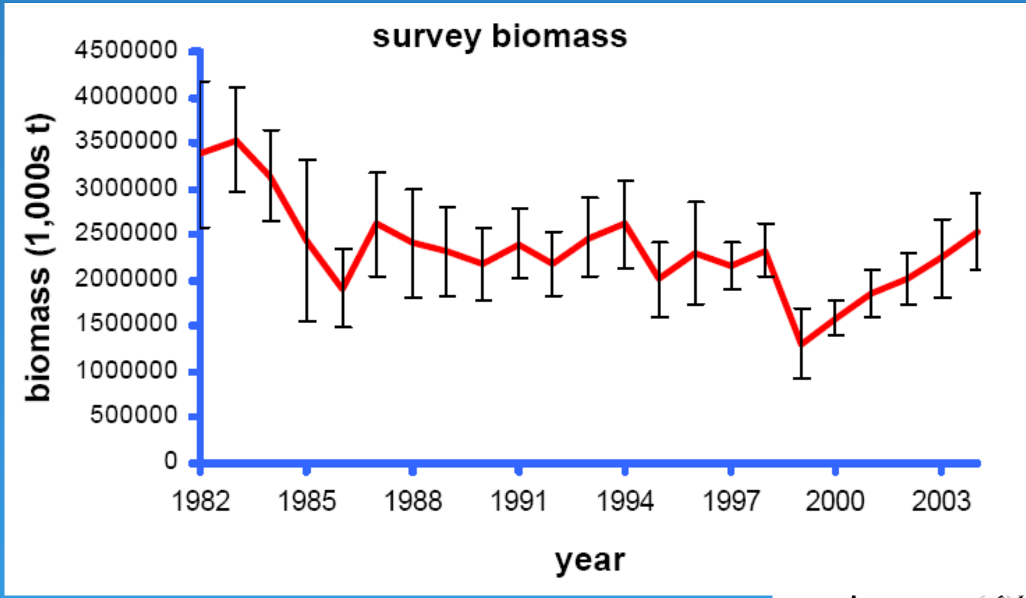
Today, 42 fisheries all around the nation are monitored by observer programs logging over 60,000 observer days at sea.

Data support fish stock assessment, fishery monitoring, protected species mortality monitoring, and other conservation and management programs.

# Pillar II - Abundance Index
# Fishery-Independent Surveys

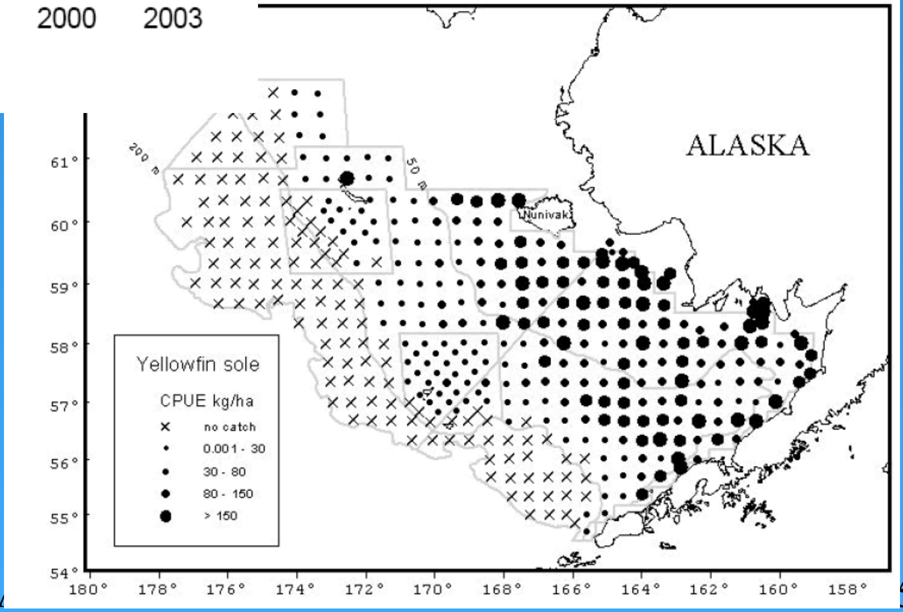
- Catch/Effort = *q* * Abundance
  - Survey sampling units (effort) is highly standardized;
  - Sampling follows a statistical design;
  - Assert that *q* is sufficiently constant;
  - Sometimes, *q* can be measured directly, so survey catch rate can be transformed directly to measure of abundance

# Fishery-Independent Surveys




10 NOAA Ships

Plus 1768 charter DAS

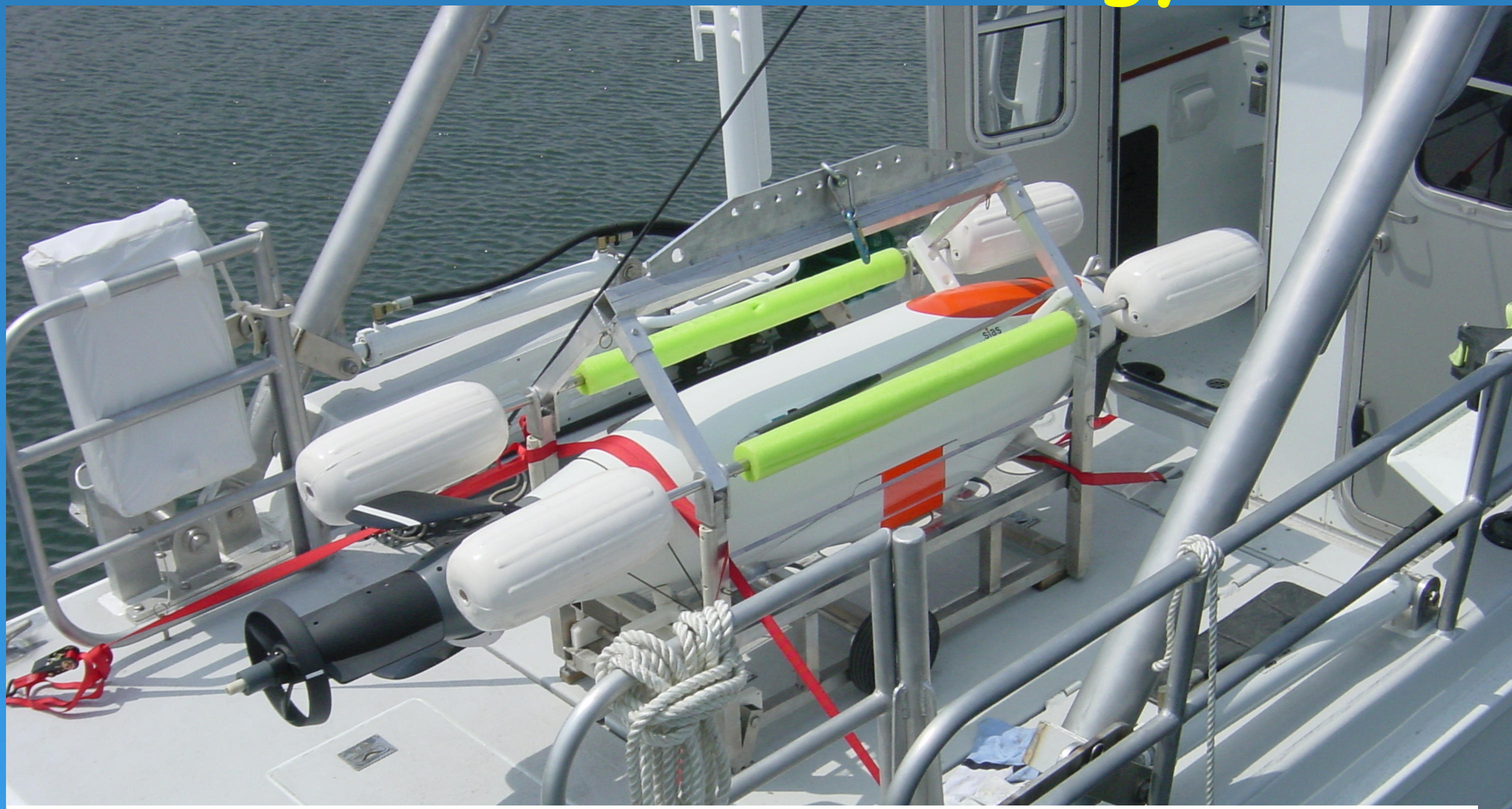


# Fishery CPUE as Abundance Index

- Fishery Catch = *q* * Effort * Abundance
  - So
- Catch/Effort = *q* * Abundance

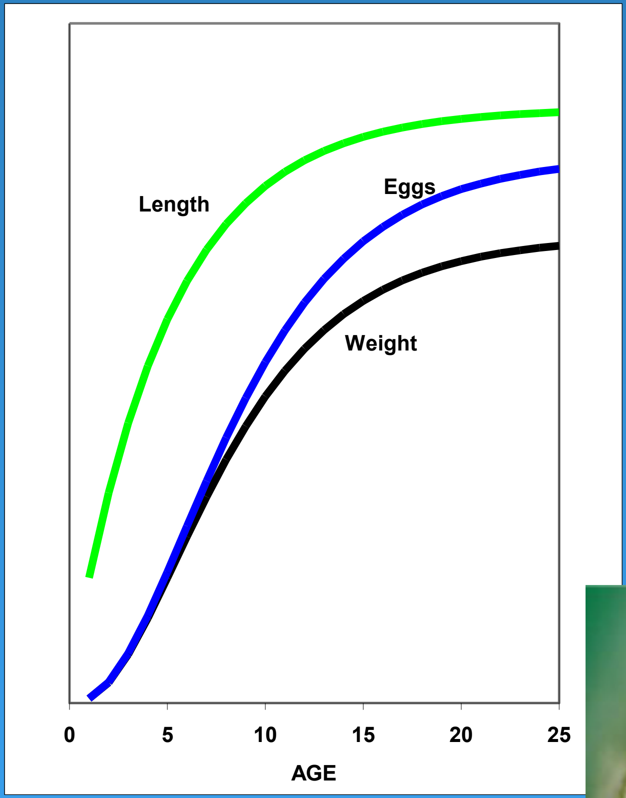
- Unfortunately,
  - Fishing effort is very hard to standardize, so the effective *q* may not be constant;
  - Fishing tends to occur where abundance is high, not where abundance is average.

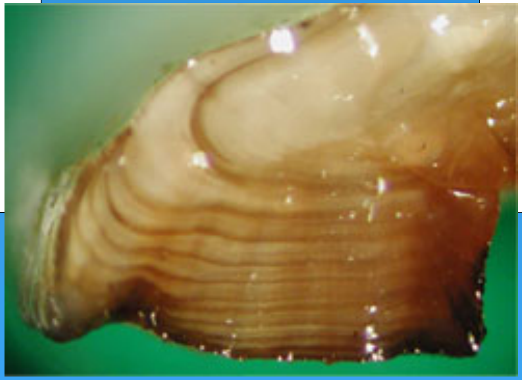
# Advanced Technology

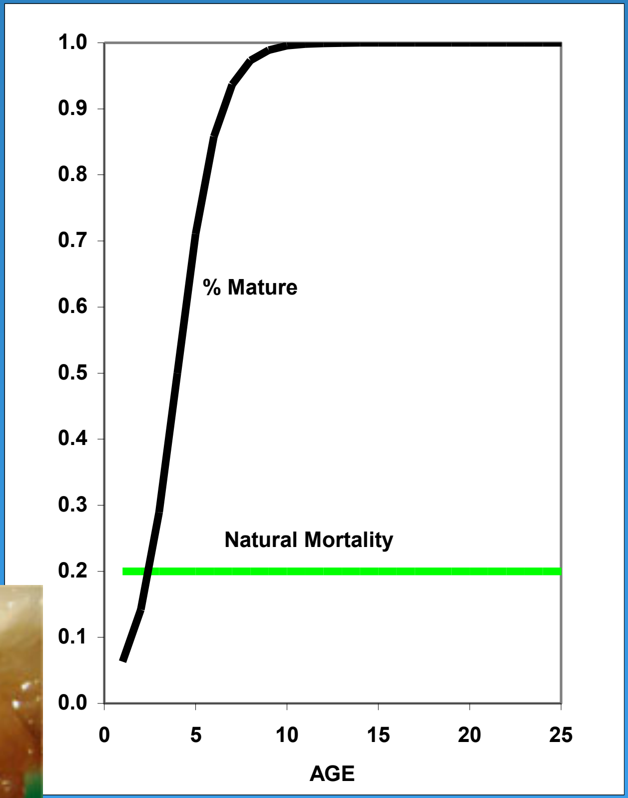


- Autonomous Underwater Vehicle
- Contains cameras, sensors, acoustics
- Reach into habitats inaccessible to other survey tools

# Pillar III - Fish Biology / Life History






Ease: Length > Weight >> Age > Eggs & Maturity >>> Mortality

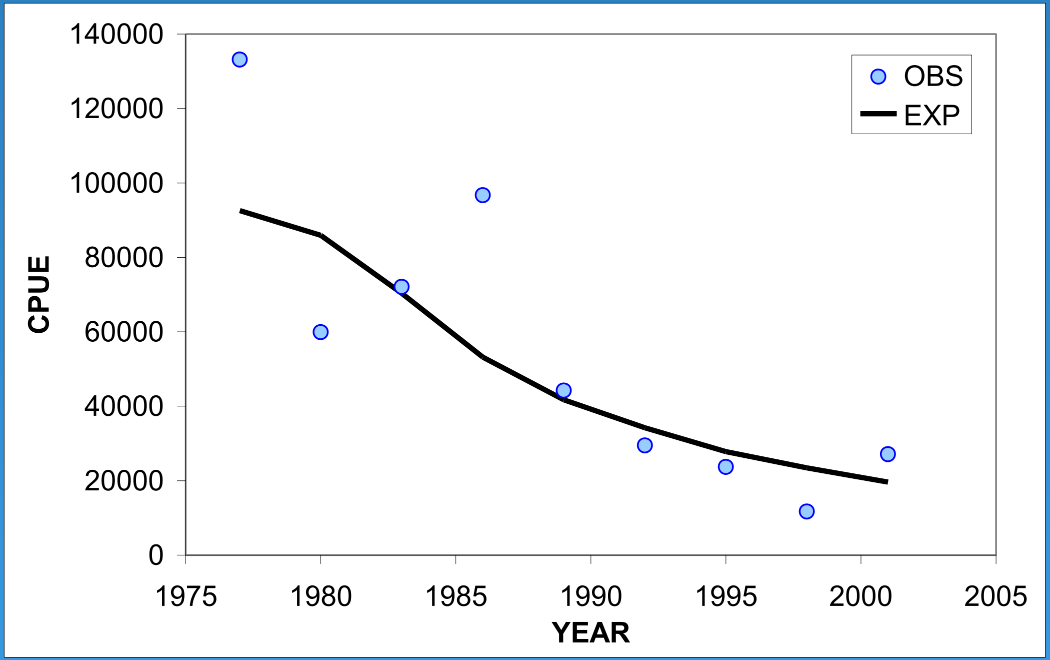
# STOCK ASSESSMENT LOGIC
## Estimating Abundance

- How big must stock have been if:
  - We saw a relative decline of *X%* per year in the survey index;
  - While *Y* tons of catch were removed per year;
  - And the stock's biology indicates that natural changes in abundance are only +/-*Z%* per year

# BASIC ASSESSMENT APPROACHES

- **Index Methods**
  - Is stock abundance:
    - Increasing, decreasing, or stable?
- **Equilibrium Methods**
  - On average, is fishing mortality:
    - too high, too low, or just right?
- **Dynamic Population Methods**
  - Estimates time series of stock abundance and mortality
  - Forecast stock abundance and catch level that maintains mortality target
  - Can be biomass-based, but age & size structure provide more detail, especially for forecasting
- *Choice depends on data availability and complexity of management questions*

# Trend in Survey Abundance Index

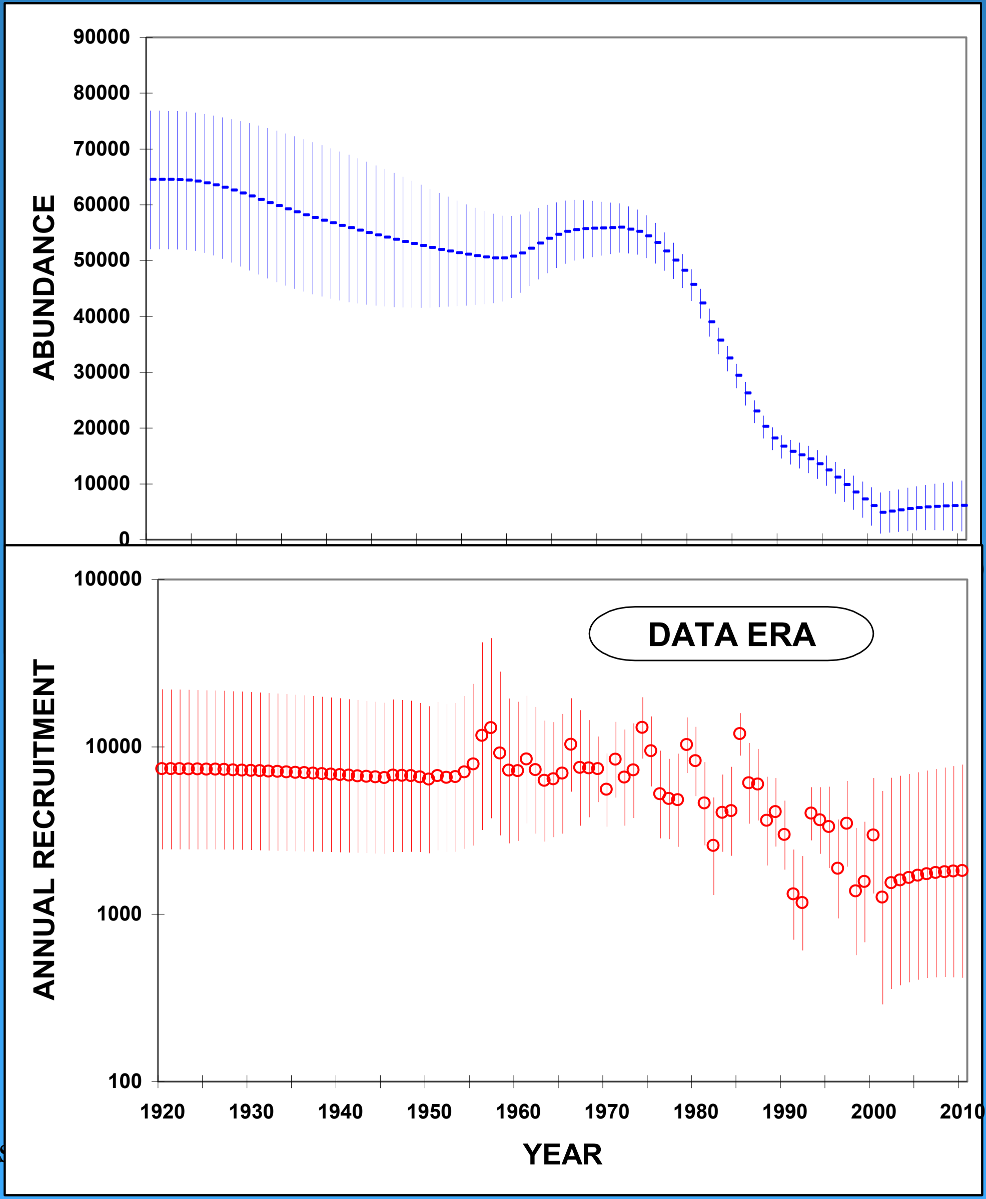



- Lack of fit due to:
  - Sampling variability of the observations
    - Environmental data can improve stratification and adaptive sampling
  - Unknown changes in the calibration, *q*
    - Environmental data can inform about changes in availability of fish to the survey

- Other Data in Model:
  - Recruitment index for some years
  - Proportion at each age in the fishery
  - Total catch

# INTEGRATED ANALYSIS

- Ability to use various age, length, abundance data to calibrate model
- Smoothly transitions from pre-data era, to data-rich era, to forecast.
- Produces estimates of model uncertainty



# MODEL PROCESSES

## VARIABLE

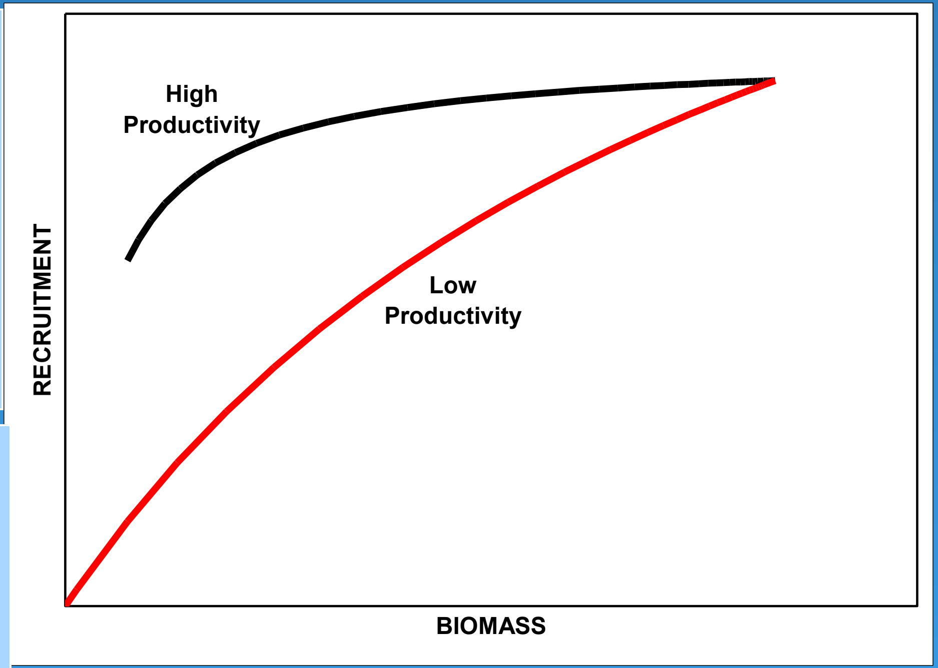
- Expected To Vary Over Time
  - Data Are Informative About Fluctuations
- Examples:
  - Fishing Mortality
  - Annual Recruitment
  - Growth and Maturity Changes

## CONSTANT

- Assert, Believe!, Hope!! To Be Stable Over Time
  - Traditional Data Provide Little Information To Estimate Variability
- Examples:
  - Natural Mortality
  - Survey Catchability
  - Average Spawner-Recruitment Relationship

# PRODUCTIVITY

High productivity stocks maintain high recruitment levels even as stock abundance declines. They rebuild quickly as fishing mortality is reduced.




Low productivity stocks can sustain only low fishing mortality rates. They require multiple generations to rebuild from low biomass levels.

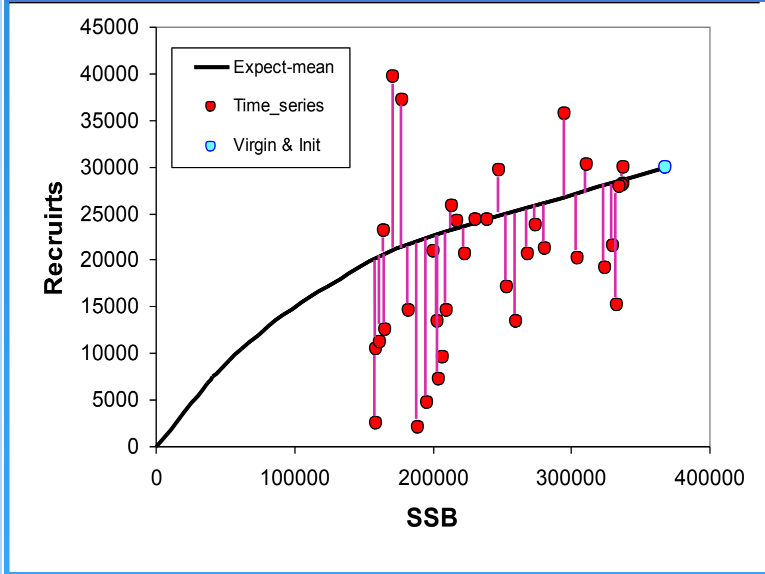
Short-term (annual) environmental variability obscures these ecological relationships

Long-term (decadal) environmental and ecosystem shifts are confounded with relationships

# ENVIRONMENTAL DATA & "VARIABLE" PROCESSES

**Recruitment = f(biomass, environment, ecosystem) + *e***

- Including environmental component in model can:
  - Reduce alias in estimate of biomass linkage caused by long-term environmental patterns;
  - Provide additional information on historical fluctuations during data-poor periods;
  - Provide early indicators of upcoming fluctuations.
- Similar situation for environmental effects on body growth
- Ecosystem effects are harder!



# ENVIRONMENTAL DATA & CONSTANT PROCESSES

- New Information About Changes In "Constant" Processes
  - Need Validation Outside Model
- EXAMPLES:
  - Predators Affect Natural Mortality
  - Spatial Distribution Affects Catchability
  - Thermocline Depth Affects Catchability
  - *PDO* Regime Affects Average Recruitment

# Fisheries And The Environment

# FATE

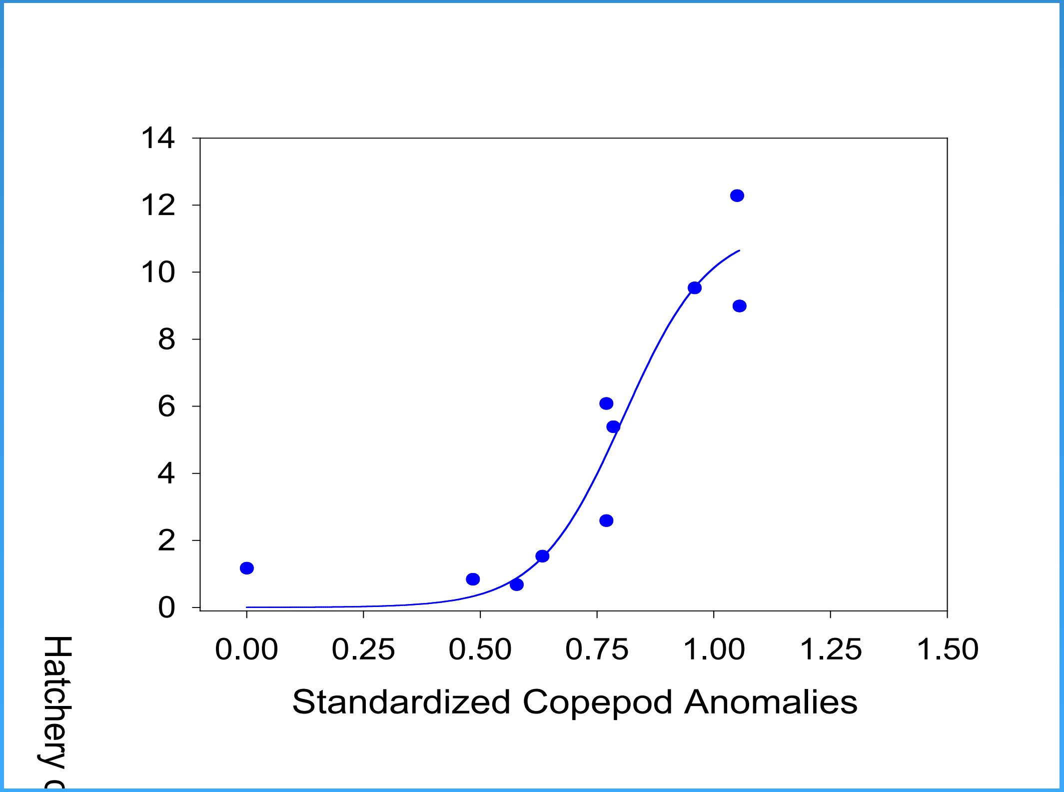
A NOAA Fisheries Oceanographic Program

Supporting NOAA's mission to ensure the sustainable use of US fishery resources under a changing climate

# A FATE Ecosystem Indicator

Peterson et al.; Northwest Fisheries Science Center

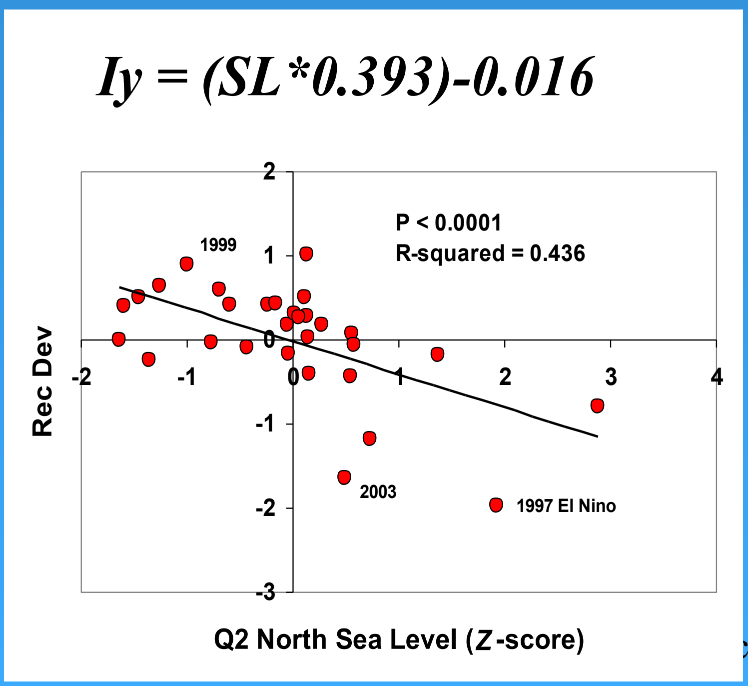
This function can be used to predict returns of salmon the following year; copepod anomalies from 2001 predict that about 10% of the juvenile salmon that went to sea in spring 2001 will return to spawn in fall 2002.



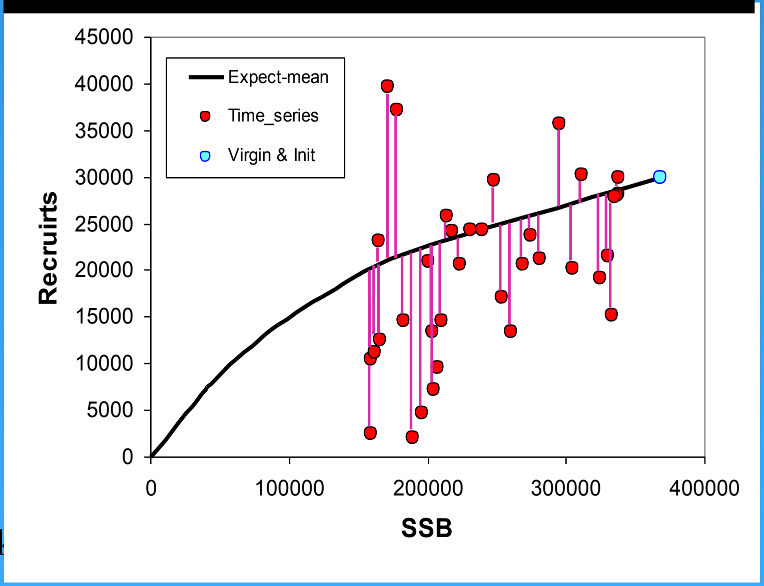
# Sablefish Recruitment Variability

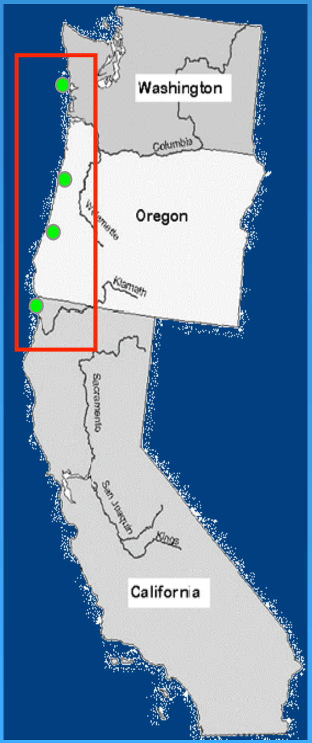
Michael J. Schirripa and Jim J. Colbert
Northwest Fisheries Science Center, Oregon State University

**Recruitment is fit to stock biomass as well as annual deviations in the Spring sea level anomalies. This made possible estimates of current year-class strengths**

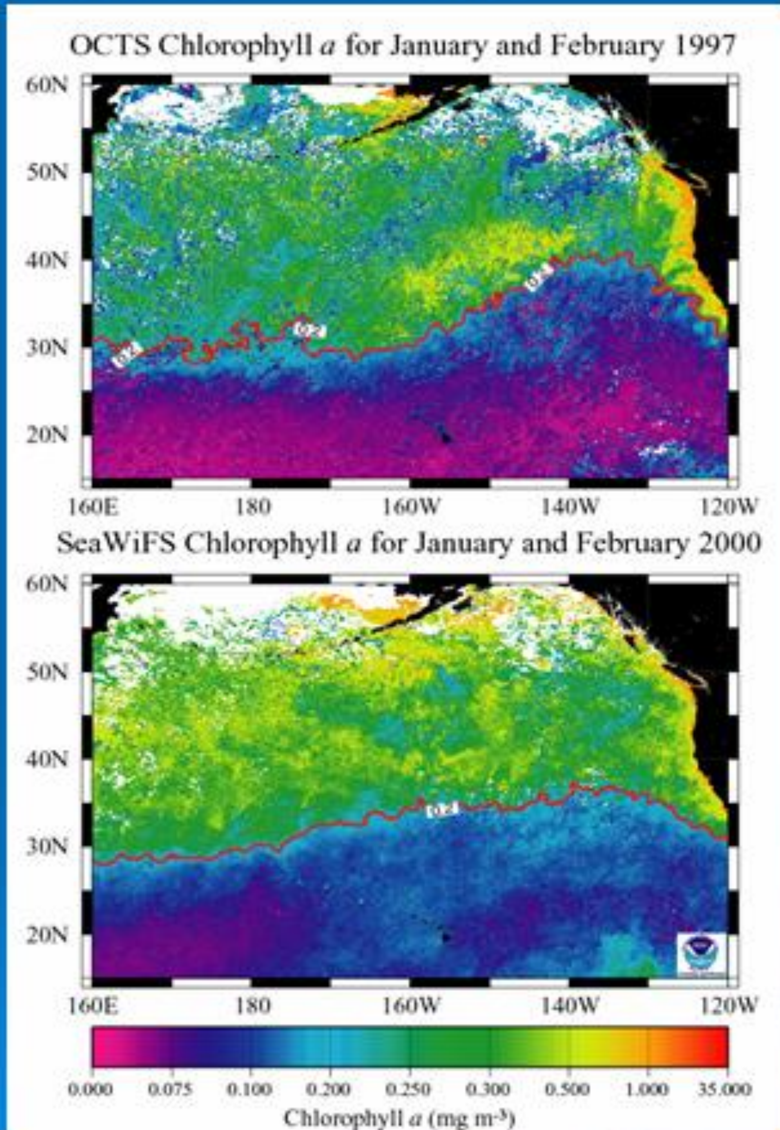



[redacted]



# TRANSITIONAL ZONE CHLOROPHYLL FRONT TZCF



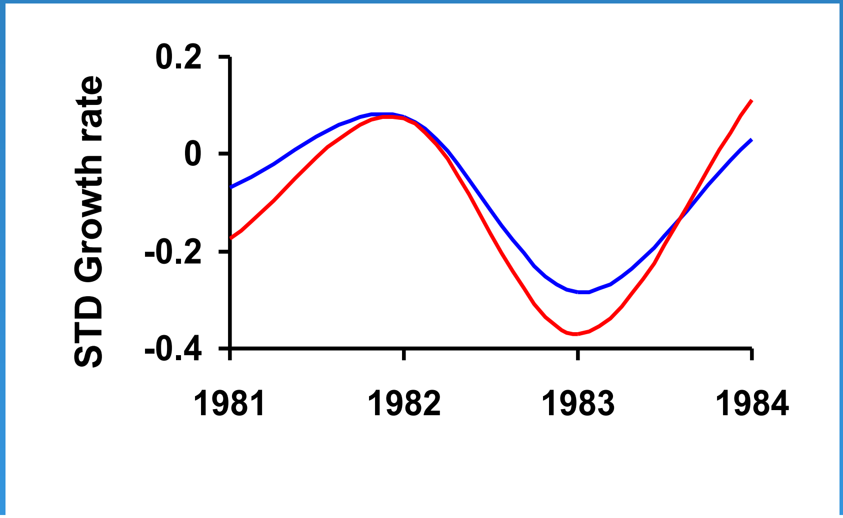

- TZCF affected by El Niño
- Key forage habitat
- Migratory corridor for:
  - turtles
  - albacore tuna
  - albatross
- Changes in location affect:
  - International fisheries
  - Gear interaction with endangered turtles
  - Productivity NW Hawaiian islands

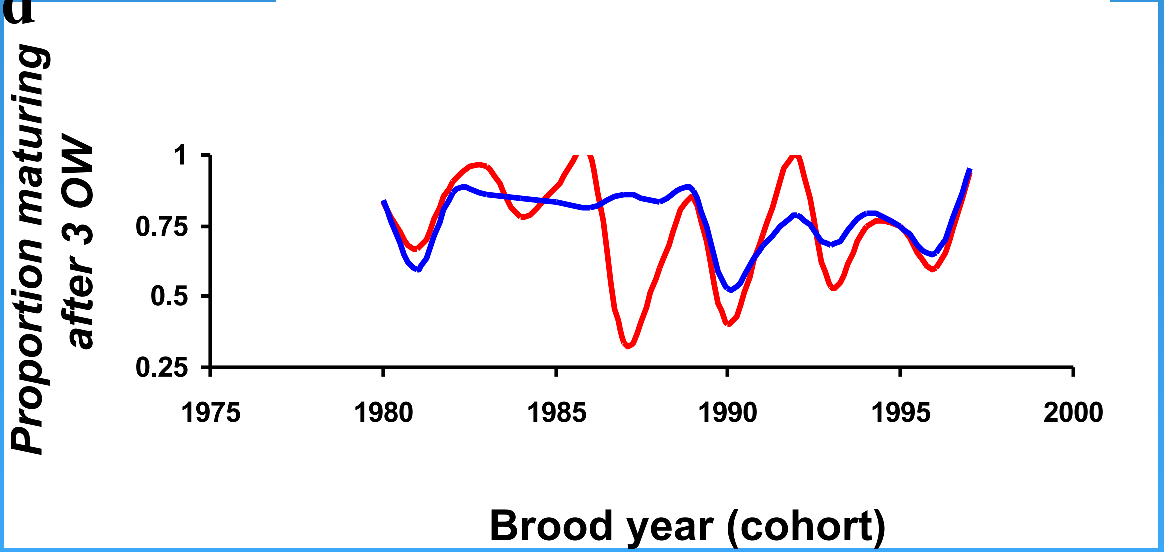
Evan Howell and Jeff Polovina, Pacific Islands Fishery Science Center

# CA Chinook Growth and Maturation Vary with the Environment

Using variables related to oceanic conditions* we can fit growth rates for individual California cohorts and the probability that a cohort will mature after the third ocean winter at sea.

*e.g. Wind Turbulence, Upwelling, Sea Level Height, Sea Surface Temperature.




B. Wells, C. Grimes, J. Field, C. Reiss, Southwest Fisheries Science Center

# CONCLUSIONS

- **Environmental information can improve precision and accuracy of fish assessments by providing:**
  - Info on large scale changes in spatial distribution;
  - Info on factors affecting fish behavior and availability to surveys;
  - Info of factors affecting spatial distribution in fishing effort;
  - Indicators to adjust mortality and growth factors otherwise held constant;
  - Indicators to forecast upcoming fluctuations in highly variable recruitment